STOCKING FOR THE FUTURE: GENETIC AND DEMOGRAPHIC CORRELATES OF WESTERN TRAGOPAN *TRAGOPAN MELANOCEPHALUS* IN CAPTIVITY

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Western Tragopan *Tragopan melanocephalus* is endemic to the Western Himalaya and is listed as Vulnerable (VU) C2a (i) in IUCN Red Data List (2011) and Schedule I of the Indian Wildlife (Protection) Act, 1972. Given the exigency of ensuring its conservation, *in situ* conservation requires *ex situ* conservation efforts for its continued survival. However, for successful captive breeding of these birds, it is critical to maintain a genetically and demographically healthy population. In this context, pedigree records through development and maintenance of a studbook offer a viable option to undertake scientific management of captive stock. We discuss the genetic and demographic status of the Western Tragopan population in the only captive facility (Sarahan Pheasantry) for the bird. We used studbook data that was analysed using population management program PM2000. The demographic traits of the population indicated a growing, but unstable population. The genetic analysis reveals a genetically healthy population with inequitable founder representation. It is suggested that population size should be grown rapidly, with a focus on increasing the 'effective' population size and breeding all the founders, thereby augmenting the genetic variability.

Key words: captive breeding, studbook, Single Population Analysis and Record Keeping System (SPARKS), PM2000, genetic analysis, demographic analysis

INTRODUCTION

Western Tragopan *Tragopan melanocephalus* is endemic to north-west Himalaya. This medium-sized pheasant, whose males are brightly coloured, possessing lappets, and fleshy horns to attract females during the breeding season, is among the rarest of the Himalayan pheasants (Ramesh 2003). Being a habitat specialist, loss of habitat poses a major threat for this species. This threat is compounded by the low breeding success, induced by direct and indirect anthropogenic disturbances. Hunting of this bird for their meat and bright plumage is another major threat for this endangered bird (BirdLife International 2001). No reliable population estimate is available for the bird; however, current estimates suggest that the wild population of Western Tragopan is lower than 5,000 individuals (Gaston *et al.* 1983; Johnsgard 1986; BirdLife International 2001; Ramesh 2007). This population is highly fragmented and reported to be declining, which adds to the risk of extinction of this bird in the wild (Ramesh 2003). The species is thus listed as Vulnerable (VU) C2a (i) in IUCN Red Data List (2011) and Schedule I of the Indian Wildlife (Protection) Act, 1972. The future of the species in the wild is thus in jeopardy, making its *ex situ* conservation through captive breeding an important conservation strategy and an insurance against extinction (Lacy 1994; Sillero-Zubiri *et al.* 1997; Budd and Leus 2011). Indeed the captive population can be used in future to infuse variation in wild population and can also be reintroduced in wild habitats, where the species has been eliminated (Foose and Ballou 1988).

A conservation breeding programme for Western Tragopan has thus been initiated at Sarahan Pheasantry in Himachal Pradesh. Incidentally, Sarahan Pheasantry is the only facility in India, and also in the world, to have captive stock of this species. Recently, two birds from Sarahan have been transferred to Kufri Zoological Park (Himachal Pradesh) for display purpose. For the successful captive breeding of the animal, it is important to maintain a genetically healthy population, i.e., maximum genetic diversity should be present in the breeding population to avoid the deleterious effects of inbreeding on future populations (Lacy 1995, 1997; Saccheri *et al.* 1998; O'Grady *et al.* 2006). Successful genetic and demographic management requires complete and accurate pedigree records, thus maintaining a studbook is primary for the *ex situ* management of any species (Ballou and Foose 1995; Foose and Weise 2006). Studbook has long been successfully used for captive breeding management of many species (Glatston 2001; Ralls and Ballou 2004; Budd and Leus 2011). A studbook for Western Tragopan has already been prepared by the Wildlife Institute of India in collaboration with the Wildlife Wing of Himachal Pradesh Forest Department (Lakshminarasimha *et al.* 2011). The present paper discusses the genetic and demographic status of the captive population of Western Tragopan using the data of the aforementioned studbook.

METHODOLOGY

The only captive population (n = 21) of Western Tragopan in India (Sarahan Pheasanty and Kufri Zoological Park, Himachal Pradesh) were assessed for genetic and demographic viability. Chronological data on the events and lineage of birds contributing to the present population were obtained from the records maintained at the Sarahan Pheasantry. Studbook was analysed using Single Population Analysis and Record Keeping System (SPARKS) 1.5 software (ISIS 2004), and a report was generated after assigning permanent studbook numbers to all the individuals in the population. Subsequently, the SPARKS dataset was imported as *.prn and *.ped files for demographic and genetic analyses to PM2000 software (Pollack *et al.* 2001). The PM2000 was then used to produce census report, life tables, founder statistics, various important genetic variables, possible pairings and population planning.

RESULTS

As on August 2011, there were 21 individuals of Western Tragopan in captivity; 19 in Sarahan Pheasantry (10 males and 9 females) and two males in Kufri Zoological Park, transferred from Sarahan in 2009. A total of 37 individuals have been kept in the Sarahan Pheasantry so far (1990 to mid 2011), however, pedigree details are available for only 22 birds, as the remaining 15 birds did not contribute to the population size. Therefore, only 22 birds were included in the population analysis.

A study of census reveals that although the population grew at a steady rate in the last ten years, there has been decline in the population size since 2009 (Fig. 1). The details of the census over the years are provided in Table 1.

Various characteristics of demography, such as age distribution, age specific fertility and age specific mortality are summarized in the life table obtained for both the sexes (Table 2). Life table suggests that the male population is growing annually (λ) at a rate of 1.07 and instantaneously (r) at a rate of 0.06, while female population is declining annually at a rate of 0.94 and instantaneously at a rate of -0.07. The average age at which the animal is producing offspring, i.e., the generation length (T) is shorter in case of females at

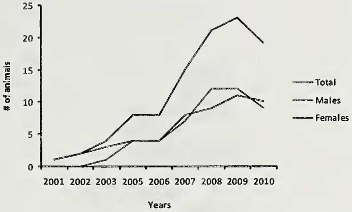

Fig. 1: Census trends of Western Tragopan in Sarahan Pheasantry

4.18 years, as compared to males at 6.45 years. Age pyramid suggests that most individuals in the given population are in the breeding age (Fig. 2). However, absence of animals in certain age classes, like juvenile and neonatal, reflected as a gap at the base of the age pyramid. Also in certain age classes, the population is prominently skewed towards one of the sex. Age specific mortality rate (Qx) for female population is high for 0-2, 2-4, 8-10, 10-12 and 12-14 age classes (Fig. 3). Age specific survivorship (Ix) is higher for males across all the age classes (Fig. 4). Age specific fertility rate or fecundity (Mx) is slightly skewed towards younger age classes for females (Fig. 5). Therefore, reproductive value (Vx) is higher for females in the younger age classes, while it is higher for males in the older age classes (Fig. 6).

Results of genetic analysis show that 86% genetic diversity is being retained by the Western Tragopan population at Sarahan Pheasantry. The gene value, which is an expression of expected heterozygosity if a given population is bred randomly (Pollack *et al.* 2001) was 0.86, which is relatively moderate. Although the current population size is 19, mean 'effective' population size (Ne), i.e., the randomly breeding ideal population that would hold the same amount of variance in allele frequency as the present population (Lacy 1995) is

Table 1: Census data of Western Tragopan in Sarahan Pheasantry

Year	Total	Males	Females	Unsexed	Wild Born	Captive Born
2001	1	1	0	0	1	0
2002	2	2	0	0	2	0
2003	4	3	1	0	4	0
2005	8	4	4	0	7	1
2006	8	4	4	0	7	1
2007	15	8	7	0	7	8
2008	21	9	12	0	9	12
2009	23	11	12	0	9	10
2010	19	10	9	0	9	10

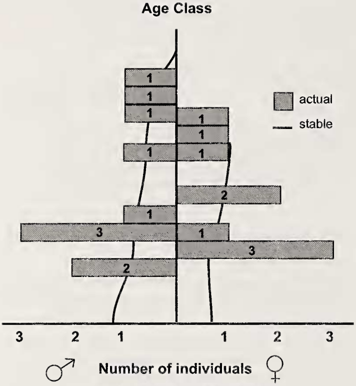

Fig. 2: Age distribution of living Western Tragopan population in Sarahan Pheasantry

only 10.63 over the past 1.3 generations. The current Ne is even lesser at 8.89. Mean kinship (MK), which is the most important genetic parameter for deciding which of the birds in the population should be given priority for breeding (Lacy 1995; Ballou and Lacy 1995; Montgomery *et al.* 1997), is high for most of the animals (Table 3). Population mean kinship is high at 0.14, but has the potential to be lowered to 0.06. It is pertinent to note that population's mean inbreeding coefficient (F) is zero. Individual statistics also reveal zero mean inbreeding in current Western Tragopan population, implying that none of the birds in Sarahan Pheasantry are inbred (Table 4).

Table 2: Age distribution of living Western Tragopan population

Age (x)	Male Actual	Male Stable	Female Actual	Female Stable
0	0	1.16	0	0.81
1	0	1.09	0	0.82
2	2	0.97	0	0.74
3	0	0.85	3	0.70
4	3	0.80	1	0.75
5	1	0.75	0	0.80
6	0	0.71	2	0.86
7	0	0.67	0	0.92
8	1	0.63	1	0.98
9	0	0.59	1	1.05
10	1	0.55	1	0.56
11	0	0.52	0	0.00
12	1	0.49	0	0.00
13	1	0.23	0	0.00
14	0	0.00	0	0.00

The founder statistics show that there are six founders with living descendants in the population. However, the Founder Genome Equivalents (FGE), which is the number of founders that would retain the same level of genetic diversity as the present population, if all the founders are equitably represented and retain all the alleles (Ballou and Foose 1995; Lacy 1995), is 3.6. Founder statistics further suggest that values of Founder Genome Equivalents and Founder Genome Surviving are low because studbook numbers 00001 (Abbu) and 00004 (Neelu) are over-represented, while studbook number 00006 (Moti) is under-represented. Studbook numbers 00007 (Rekha), 00009 (Shalu) and 00010 (Sanju) have not been represented at all, these are wild origin individuals that can be potential founders (Table 5).

DISCUSSION

The successful captive breeding of Western Tragopan at Sarahan Pheasantry has indicated that the species is capable of reproducing *ex situ*, making it possible for the managers to address the challenges of conservation breeding of the species to successfully raise a stock for future. However, the present captive population of Western Tragopan as indicated by the above presented demographic characteristics is not stable. Life table predicts a negative growth of female Western Tragopan population indicating that the female population is not demographically healthy. High Qx for female population under certain age classes also implies that the females are at a higher risk of death in these age classes than the males. Thus, it is of importance to identify the factors which are negatively affecting the female population. Skewed Mx towards younger age classes for females suggest that younger

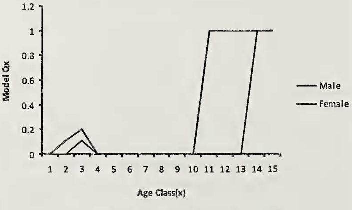

Fig. 3: Comparison of male-female mortality

females reproduce more than males in the same age class, while older males reproduce more than females in the same age class. Thus, there are probabilities that males would live longer and produce more number of offspring than females in the population. Age distribution of Western Tragopan presented as an age pyramid reveals that there are gaps at the base of the age pyramid, which may be deleterious for the population, thus neonatal and juvenile mortality needs to be checked. The caveat is that there is further scope for demographic understanding, as the present analysis is constrained by low population size. PM2000, which is an age-based model, smoothes the data by providing average for the age class, but since the given population is small, fewer animals have passed through each age class, making it difficult to make reliable predictions about the population. For this purpose it is important that the population should be rapidly increased and analysis repeated. As an alternative the population can also be analysed using stage-based models that are increasingly being viewed as a new approach for assessing small captive populations (Faust 2003).

The present population is genetically healthy as indicated by absence of inbreeding and therefore inbreeding depression (Foose and Ballou 1988; Lacy 1995, 1997). However, genetic analysis reveals that the mean kinship is high for most individuals; thus, caution should be taken to plan breeding of these animals if it is desired to keep mean inbreeding to low levels. Kinship should also be minimized to retain maximum genetic diversity in this population with unequal founder representation (Montgomery *et al.* 1997).

Fig. 4: Comparison of age specific survivorship

Further, Ne is low, indicating that the population is not efficiently maintaining genetic diversity from one generation to the next (Ballou and Foose 1995). Therefore, efficient management intervention should be undertaken that would involve increasing the 'effective' population size (Ne), than merely increasing the size of the small population. This can possibly be achieved by equalizing the sex ratio, decreasing the variability in family size, checking the fluctuations in the population size over generations and avoiding overlap of generations. Presently, it is of utmost importance to increase the population size, control fluctuations in the population size and to optimize the sex ratio (Templeton and Read 1983; Tangley 1984; de Boer 1989, 1994; Foose and Ballou 1988; Lacy 1995; Provine 2004; Lees and Wilcken 2009).

It is pertinent to reiterate that since the Western Tragopan population in Sarahan Pheasantry is under an active Conservation Breeding programme, it is helpful to breed all

Table 3: Life table for male and female Western Tragopan population

Age	Males					Females				
	Qx	Px	Lx	Mx	Vx	Qx	Px	Lx	Mx	Vx
0	0.000	1.000	1.000	0.000	1.000	0.000	1.000	1.000	0.000	1.000
1	0.000	1.000	1.000	0.070	1.065	0.110	0.890	1.000	0.060	0.993
2	0.110	0.890	1.000	0.000	1.122	0.200	0.800	0.890	0.100	1.032
3	0.000	1.000	0.890	0.000	1.270	0.000	1.000	0.712	0.330	0.984
4	0.000	1.000	0.890	0.000	1.353	0.000	1.000	0.712	0.400	0.613
5	0.000	1.000	0.890	0.250	1.441	0.000	1.000	0.712	0.200	0.200
6	0.000	1.000	0.890	0.500	1.269	0.000	1.000	0.712	0.000	0.000
7	0.000	1.000	0.890	0.510	0.820	0.000	1.000	0.712	0.000	0.000
8	0.000	1.000	0.890	0.330	0.330	0.000	1.000	0.712	0.000	0.000
9	0.000	1.000	0.890	0.000	0.000	0.000	1.000	0.712	0.000	0.000
10	0.000	1.000	0.890	0.000	0.000	1.000	0.000	0.712	0.000	0.000
11	0.000	1.000	0.890	0.000	0.000	1.000	0.000	0.000	0.000	0.000
12	0.000	1.000	0.890	0.000	0.000	1.000	0.000	0.000	0.000	0.000
13	1.000	0.000	0.890	0.000	0.000	1.000	0.000	0.000	0.000	0.000
14	1.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000

Qx = mortality; Px = survival; Lx = cumulative survivorship; Mx = fecundity; Vx = expected future reproduction the founders extensively, preferably with other founders. Moreover, all the founders in the population should be given equal chances to breed; the under-represented animals should be given priority when planning breeding, while the over-represented stock should not be bred, not at least for the conservation breeding (Foose and Ballou 1988; de Boer 1989, 1994; Foose and Weise 2006; Ballou and Foose 1995). The three wild origin individual that have not been bred should also be bred to increase the genetic diversity of the population. In addition, it is desirable that new wild origin individuals be added to the population, since it is suggested for most captive breeding programme to have 20-30 founders (Foose and Ballou 1988; Lees and Wilcken 2009). But it would be difficult in case of Western Tragopan to procure wild animals given its Vulnerable status; therefore wild origin individual animals should only be added if the goal of the program is reintroduce the birds in the wild, otherwise the captive population should be maintained as a self-sustaining population (Lees and Wilcken 2009). It is also important to ascertain founder kinship, as the genetic diversity (heterozygosity and allelic diversity) retained in the population is a function of relationship to the base population (i.e., founder individuals) (Ralls and Ballou 2004). In captive breeding programmes, the founders are assumed to be unrelated unless there are evidences against the same (Lacy *et al.* 1995; Ballou and Foose 1995; Jones *et al.* 2002; Russello and Amato 2004, 2007). The genetic analysis was therefore performed with an assumption that the founder individuals were drawn from unrelated populations (both wild and captive). Given the absence of detailed location information and DNA analysis, such an assumption needs to be validated. For instance, as per the records, the five birds [Studbook# 00001 (Abu), 00006 (Moti), 00004 (Neelu), 00007 (Rekha) and 00005 (Rani)] were rescued from Daranghati Wildlife Sanctuary, with all but Rekha and Moti being rescued in different time scale. It is, therefore, difficult to place whether or not these are from the same population within Daranghati. These uncertainties and gaps could be effectively addressed by DNA profiling these birds as has been done for another endangered bird, Whooping Crane *Grus americana* (Jones *et al.* 2002).

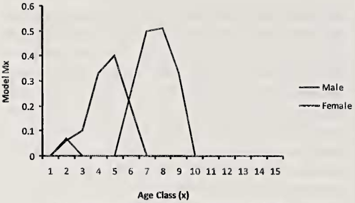

Fig. 5: Comparison of male-female fecundity

Population Planning and Management

Association of Zoos and Aquariums (AZA) Species Survival Plan (SSP) recommends certain population genetic management goal, i.e. 90% genetic diversity for 100 years.

Table 4: Individual statistics

Studbook #	Sex	Sire	Dam	Age	Known	F	MK	KV	FOKE	Progeny	Additional Ids
00001	M	WILD	WILD	13	100	0	0.09	0.08	3.8	2	Abbu 2259q
00002	M	WILD	WILD	12	100	0	0.10	0.10	4.0	5	Raja 2256q
00003	M	WILD	WILD	10	100	0	0.09	0.10	3.5	4	Joney 2258q
00004	F	WILD	WILD	10	100	0	0.09	0.08	3.8	2	Neelu 2260q
00005	F	WILD	WILD	9	100	0	0.10	0.10	4.0	5	Rani 2256q
00006	M	WILD	WILD	8	100	0	0.03	0.03	1.0	1	Moti 2268q
00007	F	WILD	WILD	8	100	0	0.00	0.00	0.0	0	Rekha 2266q
00008	F	00001	00004	6	100	0	0.16	0.13	6.5	4	Ruchi 2267q
00009	F	WILD	WILD	6	100	0	0.00	0.0	0.0	0	Shalu 2283q
00010	M	WILD	WILD	5	100	0	0.00	0.0	0.0	0	Sanju 2284q
00013	M	00003	00008	4	100	0	0.16	0.16	6.5	1	Shiv 2286q
00014	M	00001	00004	4	100	0	0.12	0.12	4.8	0	Golu 2278q
00015	M	00002	00005	4	100	0	0.13	0.14	5.0	0	Gudu 2281q
00017	F	00002	00005	4	100	0	0.14	0.13	5.5	1	Sheela 2276q
00018	F	00003	00008	3	100	0	0.15	0.14	6.0	0	Seema 2289q
00019	F	00002	00005	3	100	0	0.13	0.13	5.0	0	Lata 2290q
00021	F	00003	00008	3	100	0	0.15	0.14	6.0	0	Heena 2288q
00022	M	00013	00017	2	100	0	0.18	0.18	7.0	0	Teenu 2291q
00023	M	00006	00016	2	100	0	0.09	0.10	3.8	0	Monu 2292q

Fig. 6: Comparison of male-female reproductive value

Population modelling of captive Western Tragopan in Sarahan Pheasantry in PM2000 suggests that for achieving the population genetic management, a large number of birds would be required. Such target is difficult to achieve in the present situation, since Sarahan Pheasantry is the lone holding institution for the breeding of Western Tragopan in the entire world. Hence, a feasible genetic management goal of maintaining 90% genetic diversity for 50 years is suggested; for which a population of 52 individuals needs to be maintained with the addition of one founder per year for the next 50 years. This goal though can be achieved even with a smaller number of founders, if the genetic and demographic structure of the population is improved by breeding all founders equally and applying such practices in future that conserve maximum genetic diversity. It is, however, recommended that in case it is not possible to add new founders, as mentioned earlier, the 'effective' population size (Ne) should be rapidly increased manifold (theoretically around 500 individuals) (Lees and Wilcken 2009).

In addition, it is suggested that breeding should be done according to the pairing recommendations made in the Western Tragopan studbook (Lakshminarasimha *et al.* 2011) as the pairing options in the studbook are provided on the basis of mean kinship and inbreeding coefficient. Since the entire pedigree for the Western Tragopan population is known, these mating recommendations are reliable and it is further helpful to consider breeding history of specific pairs. The small population, thus, can be successfully managed by avoiding inbreeding and retaining maximum gene diversity. Lastly, it is desirable that an additional captive breeding centre for the species be established in the region, as keeping the entire captive population at one place (Sarahan Pheasantry) makes it vulnerable to stochastic events. The captive population can also be maintained as metapopulations (Lacy 1994; Sillero-Zubiri *et al.* 1997).

In conclusion, the Western Tragopan captive population holds great promise for successful *ex situ* conservation of the species. The genetic and demographic status of the population presented here is expected to guide scientists and managers towards the achievement of this goal.

ACKNOWLEDGEMENTS

This study was conducted under the ongoing research project on 'Reproductive Biology and Behaviour of Captive and Wild Populations of Western Tragopan in Himachal Pradesh', which is being undertaken by Wildlife Institute of India and Wildlife Wing of Himachal Pradesh Forest Department. We thank Mr. P. R. Sinha, Director and Dr. V.B. Mathur, Dean of Wildlife Institute of India, for making this possible. Mr. Mukesh Arora provided DTP help. We gratefully acknowledge Mr. Alam Singh, Block Officer cum Pheasantry In-charge, and Mr. Virender Sharma, Forest Guard; Mr. Avay Shukla, former Secretary and Mr. Ashwanii Gulati, Chief Wildlife Warden; Mr. Vinay Tandon PCCF and Mr. Sanjeeva Pandey CCF; Mr. Rakesh Sood CF (Wildlife), Mr. Satish Negi, DFO (Sarahan) and Dr. Sandeep Rattan, Veterinary Officer, for their support and efforts.

Table 5: Founder statistics

Studbook #	Sex	Age	Representation	Contribution	Allele Retention	Potential Retention	Descendants
00001	M	13	0.1875	1.8750	0.7475	1.0000	6.00
00002	M	12	0.2000	2.0000	0.9050	1.0000	5.00
00003	M	10	0.1750	1.7500	0.8765	1.0000	4.00
00004	F	10	0.1875	1.8750	0.7490	1.0000	6.00
00005	F	9	0.2000	2.0000	0.9040	1.0000	5.00
00006	M	8	0.0500	0.5000	0.5000	1.0000	1.00
00007	F	8	0.0000	0.0000	0.0000	1.0000	0.00
00009	F	6	0.0000	0.0000	0.0000	1.0000	0.00
00010	M	5	0.0000	0.0000	0.0000	1.0000	0.00

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